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BIOINFORMATICS POLICY of INDIA (1986 to 2013) – A REPORT

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Rising Powers Research

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Chapter 1

Executive Summary

Bioinformatics in India started with the launch of the BTISNet¹ by the DBT in 1986. The DBT itself had been established a earlier in 1986 and the launch of the BTISNet within a year, in many ways, legitimised not only DBT's existence, but also its importance in fulfilling India's (rather Jawaharlal Nehru's) vision of "scientific" socialism – of science at the service of Indian society (Tyabji, 2007). Not surprisingly, DBT's, and thereby bioinformatics', goal has since been overarchingly developmental, i.e. biotechnology for raising the standard of living for India's poor through job creation, skilled manpower development and development of scientific infrastructure.

From its beginning in 1986, the development of *informatics and telematics*, as bioinformatics was called in late 80's, went beyond its overarching developmental objectives to find meaningfulness in the context of "...national security as well as international competitiveness" (PCd, 1985: 17.42, 17.52). In the late 80's, *informatics* was a tool for computerising or modernising existing systems and while the word was frequently used in conjunction with biotechnology, it was by no means its only association. Rather, the term *Informatics* appears to have loosely embodied the message of modernisation – to project an image of a 'modern India' through the use of modern 'western' tools in use in the west. It wasn't until the mid-90s, and after the political turmoil of the early 90's, that the bioinformatics sector began to take shape.

Tangible policy objectives were identified to help develop the sector such as entrepreneurship development initiatives to attract private sector engagement, setting up biotech/bioinformatics infrastructure to facilitate entrepreneurs and attract researchers in the field, budgetary allocation earmarked for "bio-infor-matic systems" (PCe, 1992; 18.4.6; 18.5), etc. At the same time, there was recognition of a lack of indigenous expertise and experts. This resulted in policies for 'International Cooperation' becoming much more detailed at the same time policies sought to move away from the nations' immediate geopolitical sphere of influence in favour of academic and industry linkages with R&D

¹ Biotechnology Information System (BTIS) network "to create an infrastructure that enables it to harness, biotechnology through the application of Bioinformatics" (DBT, nd).

centres farther afield to, primarily, initiate north-south technology transfers (PCe, 1992: 18.3.42).

By the mid to late 90's "Genetic engineering units and a network of bio-infor-matic system" were among the first 11 "national infrastructure facilities" set up under the DBT (ibid: 18.5.31). The "International Centre for Genetic Engineering and Biotechnology (ICGEB)²," was created in New Delhi as one of the 3 autonomous research institutes promised by the 8th five-year plan. ICGEB, in 1994, became an autonomous centre under the United Nations Industrial Development Organization (UNIDO) with India and Italy becoming its largest funders; ICGEB's current membership covers 64 countries, with an additional 21 pending ratification. 'Genome mapping and sequencing' became a 'thrust' area of DBT with the stated goal of "strengthening, expansion and operationalisation of a country-wide network in bioinformatics" (PCf, 1992: 10.1.35). The Indian Space Research Organisation (ISRO) INSAT (Indian Satellite) jointly with Department of Information Technology (DIT), Ministry of Communications and Information Technology launched the telemedicine³ network including telepathology (Mishra et.al, 2009), in 1999 The Sanjay Gandhi Postgraduate Institute of Medical (SGPGIMS) Lucknow, a pioneer in telemedicine since early 2000's, currently boasts global linkages and has launched a School of Telemedicine and Biomedical Informatics to develop informatics skills. Today, India's telemedicine network is connected via V-SAT to the 53 *Heads of State* network in the *Pan-African e-Network* including 53 hospitals and 53 learning centres; the South Asian Association for Regional Cooperation (SAARC) countries telemedicine networks; the Oregon Health and Science University, Portland, USA etc (see <http://www.sgpqi-telemedicine.org>) etc.

Aided by India's economic liberalisation of the early 90s, the biotechnology sector saw a spate of policies that may have provided the early catalyst for the sector's eventual success. However, the extent to which success may have been the result of a lucky mix of global and local circumstances instead of home-grown policies is debatable. In any case, the biotech policy mix was varied; targeting entrepreneurship development initiatives to attract private sector engagement, setting up biotech/bioinformatics infrastructure to facilitate entrepreneurs and attract researchers in the field, reversing brain drain to developed countries and creating budgetary allocations earmarked for "bio-infor-matic systems" etc (PCa, 1992; 18.4.6; 18.5; 18.3.35), etc.

A vision statement for the biotech sector, the document 'Biotechnology - A Vision - Ten Year Perspective' (*Vision* hereafter) was presented by Prime Minister Vajpayee on September 7, 2001. *Vision's* intended objective was to manage and boost the unprecedented growth in the drugs and pharmaceuticals sector in the preceding years. *Vision's* stated vision was "attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor" (DBT, 2001). Genomics and Bioinformatics were ranked as the top two biotech areas in the list of focus areas earmarked for public support. A primary target

² <http://www.icgeb.trieste.it/about-the-centre.html>

³ Defined as "remote monitoring of physiological data e.g. temperature and blood pressure that can be used by health professionals for diagnosis or disease management. ...also covers the use of information and communication technology for remote consultation between health professionals or between a health professional and a patient e.g. providing health advice by telephone, videoconferencing to discuss a diagnosis or capturing and sending images for diagnosis" (Royal College of Nursing; see http://www.rcn.org.uk/development/practice/e-health/telehealth_and_telecare).

for bioinformatics was building world-class infrastructure “data warehouses, ... mirror sites to decipher the international data...” and supporting cutting-edge speciality informatics-of-the-future like neuroinformatics. Another equally important target was in the area of skilled manpower acquisition and development (see 10th plan). Efforts to reverse the brain drain to developed countries, a policy target from the mid-90s, gained momentum during this time. Attracting eminent Indian Diaspora to lead national centres of excellence provided the best solution for bridging the indigenous knowledge gap and becoming more self-reliant as a nation. At the same time, the Diaspora provided ready linkages to globally renowned research institutions without India entering into costly international collaborations with developed countries that were increasingly viewed with distrust (a well documented fact) as advantaging those countries at India’s expense.

By 2002, the developmental objectives of skilled manpower development and skilled job creation began to be subsumed within aspirations of ‘global leadership.’ Bioinformatics was chosen as one of the fields that was “expected to be all pervasive and have far-reaching impact” in India’s bid to become a global leader (PCg, 2002; 10.159). That India desired to be a global leader, “in selected fields” and bioinformatics, was evident, given the nation’s globally successful experience in IT and pharmaceuticals. The proposed bioinformatics expansion plans involving substantial public spending commitments are testament to that fact.

In-line with this global leadership aspirations for bioinformatics, the basic research in bioinformatics and nanotechnologies were earmarked for long-term R&D public funding under the funding category of projects that are “uncertain and the gestation period could be more than 10 years. ...unattractive for private sector funding” (ibid: 10.161). Interestingly, “large database” development was earmarked for short-term funding, i.e. projects with 1-3 year gestation periods, “immediate commercial potential and, therefore, should be funded to a large extent by industry with minimum support from the government funds” (ibid). International bids to collaborate with India in bioinformatics appears to have been quantitatively substantial enough to have allowed India to cherry pick alliances- “Cooperation with India has been sought by several countries in this emerging field of Bioinformatics in view of the progress made and expertise developed” (BTIS, nd). India’s Apex Bioinformatics centre was designated as a referral center for UNDP/FAO/UNIDO’s regional agricultural information network/database (FARM programme). Already, the DBT networked with similar centres in China, Indonesia, Philippines, Thailand, Vietnam, Israel, Poland, Turkey and Malaysia, while BTISNet, launched in 1986, continued to expand and currently covers 65 institutions nationwide, generating 1200+ bioinformatics peer-reviewed publications.

MSc/Mtech programs in Bioinformatics were launched. The National Board of Accreditation (NBA) of technical education joined the ‘Washington Accord’⁴ as a provisional member to “ensure acceptance of its accreditation procedure amongst the member countries of the Accord” (IEA, nd). India hosted The Fifth International Conference on Bioinformatics (InCoB 2006) jointly organized by Department of Biotechnology, Govt. of India New Delhi, Jawaharlal Nehru University, New Delhi and Indian Institute of

⁴ Estb 1989; international benchmark for engineering degrees; initial signatories UK, Ireland, USA, Canada, Australia, New Zealand (IEA, nd).

Technology Delhi, under the aegis of Asia Pacific Bioinformatics Network (APBionet). 400 scientific presentations are made on seven different Bioinformatics topics.⁵ The Bioinformatics Policy of India (BPI-2004) was presented in 2004.

By 2007-2008, at a time of global growth, India's ambition of global leadership in biotech, which began to take shape in the mid-noughties, became a well documented end-point. DBT's "**ultimate objective** is to make India globally competitive in the emerging bio-economy..." (PCh, 2007: Chapter 8.54 (pp177)), while the 11th plan presented in 2008 stated that "capabilities in S&T, therefore, are reckoned as a benchmark for establishing the status of the development of a nation. **India must occupy a frontline position in this listing [highlighted in bold for emphasis]**. The Eleventh Five Year Plan approach to S&T will be guided by this **ambition** and emphasis will be on" basic research (PCh, 2007: Chapter 1.3.48 (pp30)). The rhetoric is undeniably nationalistic and ambitious, although, only a handful of sectors were chosen to deliver these goals, namely medical bioinformatics and nanobiotechnology applications among a few others (PCh, 2007: Chapter 8.55 (pp178)). At the same time, the Department of Information Technology (DIT) was focused on grid computing, high performance networking, bio-informatics, nanotechnology and even going beyond bioinformatics to the next step "convergence of bio-info-nano technologies and cognitive science" (PCh, 2007: Chapter 12.2.25 (pp437)).

The challenges to achieving the global leadership goals were numerous, ranging from regulatory and funding deficits to skilled manpower shortages. In response, the policy solutions were developed along different strands ranging from innovative funding mechanisms and support for public-private partnerships to establishing clusters, rejuvenating universities with Bioinformatics courses and certifications, expanding infrastructure in higher supercomputing capabilities, biogrid, human resource development and linkages with industry. Additional emerging areas of R&D support were also identified, such as "genomics, proteomics, pharmaco-genomics, and in-silico drug design" (PCh, 2007: Chapter 8.58 (pp178)). Several bioinformatics research institutions were setup with proposals for three autonomous Translational Molecular Medicine Centres" (PCh, 2007: Chapter 8.61 (pp179)); Advanced Centre for Protein Informatics, Science, Engineering and Technology; 50 centres training and research institutes in Biotechnology, Bio-informatics, Nano-materials and Nanotechnologies etc. (PCh, 2007: Chapter 1.3.47 (pp30)).

DBT launched the 'National Biotechnology Development Strategy', in 2007 (NBDS, 2007; see comparison table of NBDS 2007 and 2014 at the end of the 12th plan). Within DBT's 'global leadership' goals, *Bioinformatics* appears to be everywhere. For instance, the 11th plan's focus areas are (note: this is the 11th plan's focus areas, not just DBT's goals and thus they are shared by DBT, SCIR, CSIR, DIT etc) "...medical bioinformatics, ...Nanobiotechnology applications for drug, delivery, biosensors, microbial prospecting for novel compounds, genes..." (PCh, 2007: Chapter 8.55 (pp178); for details achieved per plan period, please see Chapter 2). However, it must be noted that these proposals for expanding the bioinformatics sector are still focused on skilled manpower development/acquisition, expanding state-of-the-art infrastructure and funding mechanisms.

⁵ <http://www.scfbio-iitd.res.in/seminar/incob.htm>

In contrast to the exuberance of all things related to bioinformatics in the 11th plan (presented in 2008 for the 2007-12 period), the 12th Plan (presented in 2013 for the 2012-17 period) is muted (rather almost) silent on the subject of bioinformatics. For instance, the 12th plan proposes e-governance, e-security, e-learning etc but no e-health. There are proposals to expand or launch computerised databases of patient records etc at various levels, tele-medicine nodes, but little or no involvement with classical bioinformatics. Even the report on the 11th plan's achievements (contained within the 12th plan document) never mentions the word informatics or bioinformatics (PCi, 2013: BOX 8.4: (pp 250)).

In contrast to the 2007-2008 period, the biotechnology policy directives in the aftermath of the 2008-09 global recession were muted, (almost) silent, on the subject of bioinformatics. Policy engagement with bioinformatics appeared to be restricted to proposals expanding or launching computerised databases of patient records at various levels, increasing tele-medicine nodes etc. Notably, the 2011 *Report of the Working Group on Biotechnology* (RWGoB, 2011) under the aegis of the DBT, produced a detailed report of gaps, challenges and recommendations for developing/expanding the bioinformatics sector without broaching the subject of entrepreneurship as either a gap, challenge, or as an area needing policy support. The RWGoB was intended as a guiding report for the 12th Five Year plan's biotech strategy although, interestingly, very little of its bioinformatics-related recommendations made it to the actual 12th plan document.

Today, after almost 25 years of bioinformatics policy targeting development of skilled manpower and acquisition of eminent scientific Diaspora, the sector is dominated by eminent academics-scientists with few incentives for exchanging the lab for the factory floor. The result is low levels of entrepreneurial activity with few 'business-minded' leaders to lead commercialisation. *As of 2011, there were 200 bioinformatics companies ... (needs accurate data from a reliable source)*. In reality, the private sector consists of only a handful of organisations (see table 1 below). This bleak scenario is made worse by little or no private sector funding with private investors, VC's stymied by regulatory uncertainties (which regulations apply – are regulations IT oriented or biotechnology based?), uncertain scientific outcomes and skilled manpower shortages. For instance, the Burrill Report (2014: 16) notes,

“there is, however, an urgent need for regulation of bioinformatics as regards the safe and ethical use of personalized data on platforms accessible by multiple parties or even the public at large. The absence of a regulatory framework to control and monitor the access to genomic data can compromise use of the information and serve as a drag on the growth of the sector.”

The bottom line being that the GoI remains the primary funder (with a handful of exceptions) in bioinformatics. In summary, this preliminary study suggests considerable barriers to enter India's bioinformatics sector and further research would be helpful in revealing the factors underpinning the lack of entrepreneurial activity.

Table 1

Top 5 Bioinformatics Companies by Revenue (2011-12)

RANK	COMPANY	WEBSITE	REVENUE IN \$ MILLION 2011-12	REVENUE IN \$ MILLION 2010-11
1	Strand Life Sciences	www.strandls.com/	49.14	42
2	Ocimum Biosolutions	www.ocimumbio.com/	49	65
3	Molecular Connections	www.molecularconnections.com/	48.9	-
4	Geschickten	geschickten.com/	0.45	0.65
5	NovoInformatics	www.novoinformatics.com/	0.2	-

Source- Biospectrum, June 2012, List of Top 5 Bioinformatics companies

Notably, and in contrast to the above conclusion, industry reports predict a promising future, at the same time acknowledging the current low levels of entrepreneurial activity in the sector. For instance, in 2012 the Federation of Indian Chambers of Commerce and Industry (FICCI – a GoI organisation) predicted that “In 2011-12 the sector recorded a growth of 9.6 percent clocking Rs 265.7 crore in 2011-12 ...the continual increment in the healthcare expenditure amongst Indians is fuelling growth in the market” while acknowledging that the “Indian bioinformatics market, which is the smallest of biotech industry segments constituting barely 2% of the market share in overall revenue” (FICCI, 2012). Similarly, Chakrabarty and Agooramoorthy (2010: 3) noted,

“The bioinformatics industry is rapidly expanding around the IT service centres. As a result, companies based in south India where the IT hub is located (Bangalore, Hyderabad and Chennai) vis-a-vis few companies in the north India. The south Indian key players are Infosys Life Science, GVK Biosciences, Jalaja Technologies, Kshema Technologies, IBM India, Strand Genomics, and TCS. In New Delhi, companies such as HCL Life Science, Mascon Life Science, Labvantage Solutions, SAS India, and Life Sciences Technologies are performing well.”

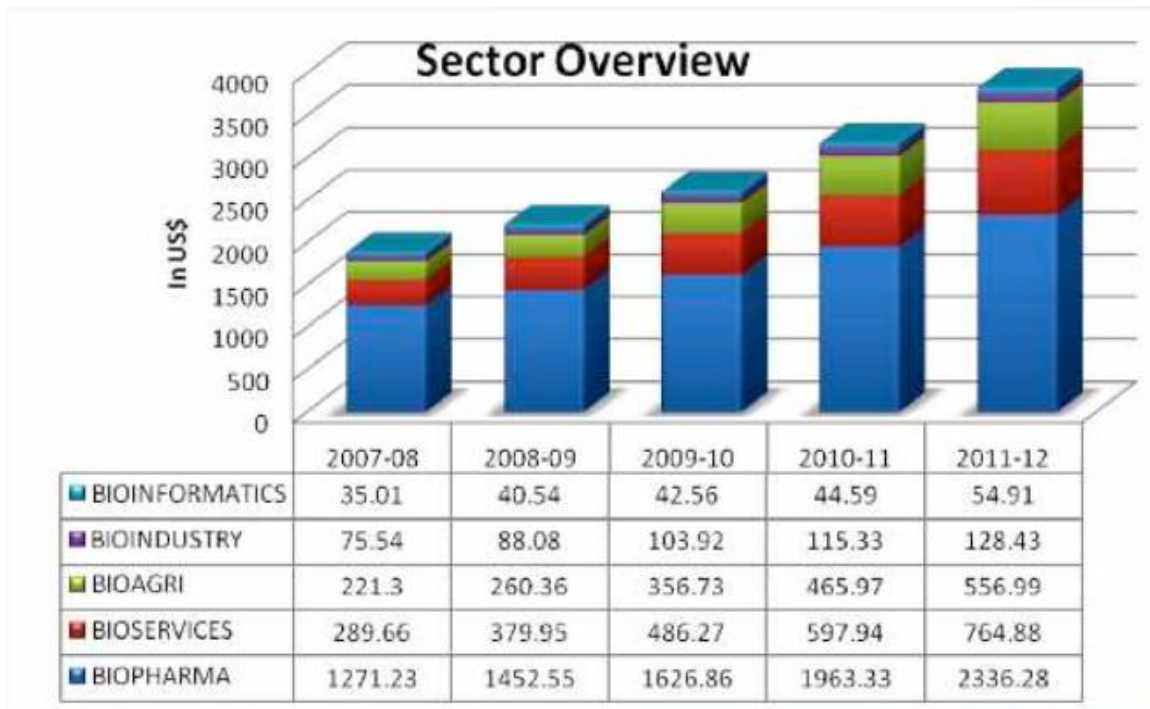
While Burrill Report (2014: 8) concluded that “Though bioinformatics represents the smallest of India’s biotechnology sectors having generated just a little more than 1 percent of the industry’s revenues in fiscal 2013, it is an area of growing importance and opportunity.”

According to the Federation of Indian Chambers of Commerce and Industry (FICCI – a GoI organisation; FICCI, 2012: 10) report on BioInformatics:

“In 2011-12, the sector recorded a growth of seven percent clocking. ...The sector had witnessed an increase in the domestic revenue during last year. This rise was attributed to factors such as an increase in public funding towards research and development (R&D) from the Government of India, decline in costs of human genome sequencing, increase in R&D investments by companies, and an increase in the number of orders for contract research activities. The sector recorded a growth of 9.6 percent clocking Rs 265.7crore in 2011-12.

The Indian bioinformatics market, which is the smallest of biotech industry segments constituting barely 2% of the market share in overall revenue, grew by 11.5% in FY 2010-11 to reach US\$ 58 Million. Tata Consultancy Services (TCS) and Council of Scientific and Industrial Research (CSIR) have launched 'Bio Suite', the country's first comprehensive

software for bioinformatics, which caters to the needs of fields such as biology, post-genomic drug discovery and other related areas. Bio Suite was developed under the New Millennium Indian Technology Leadership Initiative programme (NMITLI). Indian bioinformatics market is focused on biological database creation and management; data analysis and visualisation tools; and services and IT infrastructure. Companies from IT and life science sectors are gradually gaining traction in the bioinformatics industry by developing innovative products and services. Rising R&D activities coupled with the favourable government activities is primarily driving the market. Further, the continual increment in the healthcare expenditure amongst Indians is fuelling growth in the market.”



Biospectrum-ABLE, 2012 in FICCI, 2012.

Chapter 2

Details by Plan Period

Seventh Plan (1985-90)

Before 1985

The Government of India's (GoI's) efforts to create a separate institution for managing India's foray into biotechnology led to the creation of the National Bio-Technology Board (NBTB) under the Department of Science and Technology (DST) in 1982. The NBTB was "inter-ministerial" (i.e. not yet a separate department or interdepartmental) with a mandate of using biotechnology for fulfilling national developmental objectives in "agriculture, medicine and industry" (PCc, 1985). Several large-scale projects were proposed as part of the Sixth Five Year Plan, but failed to take off (Ramani and Guennif, 2014: 195).

1985-90

The Department of Biotechnology (DBT) was created in 1986 to replace the NBTB. However, there is no mention of a separate biotechnology policy or biotechnology department until the 8th Plan in 1990. The 7th plan's S&T policy emphasis was on "skilled manpower" as below,

- i) creating opportunities for skilled-job creation,
- ii) developing the 'technological' skills of the Indian labour force in line with the latest and promising future technologies,
- iii) reversing brain drain and appointing eminent "scientists and technologist" to run the newly created institutions (see Quote 2; PCd, 1985: 17.45, 17.48, 17.56) through "lecture assignments, consultancy in industry and assistance in setting up pilot projects in India" (17.141).

Under the Seventh Five Year Plan, development of *Biotechnology* projects were listed as an objective under 'Industry Perspective' (with the public sector acting as a "pace-setter" for boosting emerging technologies) and 'Agricultural perspective' (linking agri-science and industry to increase factor productivity).

For the first time, we find mention of the word *informatics* in India's S&T policy as a "new developing area" earmarked for public support focus and "...relevant to national development, but very important from the viewpoint of national security as well as international competitiveness" (PCd, 1985: 17.42, 17.52). Notably, *informatics and telematics* were ranked second among the 11 focus areas identified (ibid). Similar to the national biotechnology policy, focusing public support on the development of a 'technologically' skilled labour force became the primary strategic objective for developing India's informatics capabilities; it helped fill the "...need to weld the new field of informatics to the educational system (ibid, 17.91 (quote) and 17.114). 'Skilled manpower' was expected to link science to industry and bring the fruits of science to the Indian population i.e. fulfil developmental goals, empower the weak and other similar social objectives (PCd, 1985: 17.45).

The 7th Plan also promised to develop the "information base" by setting up a National Science and Technology Information System that would cover "both bibliographic and technical information required for scientific work, as well as an integrated data-base for decision-making and policy formulation in the field of S and T" (ibid, 17.115). The National Science and Technology Information System was to be created jointly by the Department of

Electronics, Dept of Science and Technology (DST), Council for Scientific and Industrial Research (CSIR), Department of Environment, Defence Research and Development Organisation (DRDO), Indian Council of Agricultural Research (ICAR), Indian Council of Medical Research (ICMR), Controller General of Patents, DGTD etc. Towards this end, policies encouraging R&D spending by industry were noted, ranging from manpower development to partnerships with research institutions etc.

However, a word of caution that while *informatics* was considered a ‘thrust area’ for S&T policy; its understanding was much broader than simply *bio-informatics*. For instance, the 7th Plan notes that *informatics* was to be a tool in office management “Office management should be modernised by the replacement of conventional methods with modern equipment. The capabilities that are available through recent developments in informatics should be fully assimilated” (17.147). Thus, *Informatics* was a tool for computerising or modernising existing systems and while the word was frequently used in conjunction with biotechnology – it was by no means its only association.

“India was the first country in the world to establish, in 1987, a Biotechnology Information System (BTIS) network to create an infrastructure that enables it to harness biotechnology through the application of Bioinformatics” (DBT, nd). Today, it is an extensive nationwide network connecting 120 institutions (under the DST, CSIR, ICMR, ICAR, Universities and Institutes under Human Resource Ministry). BTISNet aims to develop bioinformaticians and bioinformatics research. According to DBT (nd) BTISNet researchers have published 1000+ peer reviewed bioinformatics papers in the last five years and 3000+ papers in other areas of biotechnology that has led to entrepreneurial spin-offs e.g. Biosuite of Tata Consultancy Services (TCS) or software packages for visualisation of bioinformatics data by Strand Genomics. BioGrid India – a high bandwidth nationwide Virtual Public Network (VPN) for linking BTISNet institutions (discussed later in the 12th Plan), is also a BTISnet spin-off.

1990-97 (Eighth Five Year Plan 1992-97)

Target Growth: 5.0%

Actual Growth: 6.01%

The focus remains the same as the Seventh Plan period although the policy approach becomes more detailed based on experiences (i.e. mostly failure to meet 7th Plan targets). For instance, “Entrepreneurship Development Cells in all science/engineering/IITs and other academic institutions by the concerned Central/State agencies” were proposed to reverse brain drain, and encouraging the ‘entrepreneurial’ spirit started to become a policy goal. Six Science and Technology Entrepreneurship Parks (STEPs) were created. (PCe, 1992: 18.4.8). ‘International Cooperation’ became a much more prominent vehicle for achieving the national ‘employment’ based goals of the 7th Plan. For instance, there was a move to identify and drop the less productive relationships (which so far had been based in India’s immediate geographic region) in favour of industry linkages with R&D centres abroad, primarily with north-south technology transfer goals (PCe, 1992: 18.3.42). The National Register of Foreign Collaborations (NRFC) (18.4.10) and the Interface for NRI scientists and Technologists (INRIST) were established. (18.5.21).

Most importantly the 8th Plan mentioned “bio-infor-matic system” for the first time under the separate heading of *Biotechnology* (PCe, 1992; 18.4.6; 18.5). This was in-line with the

establishment of a separate Department of Biotechnology (DBT) in 1986 with the stated goal of "...development of specialized manpower and infrastructure ...and a very strong base of R and D" (18.5.6). Bioinformatics was identified as one of the tools for meeting DBT's goals, in-line with the national S&T's policy's developmental goals of increasing i) skilled labour, ii) employment with a focus on skilled employment, iii) using science for raising living standards and the weakest sections of society. For the first time, informatics, one of the three "emerging domains of high technology," was named in the biotechnology budget outlay (18.5.31).

"Genetic engineering units and a network of bio-infor-matic system" were among the first 11 "national infrastructure facilities" established under the newly created DBT (ibid). Biotech departments were created in 26 universities and the "Biotechnology Consortium India Limited (BCIL) a bioventure company" was created "in collaboration with industry and financial institutions with a view to facilitating commercialisation of biotechnology in India" (ibid).

1997-2002 (Ninth Five Year Plan 1997-2002)

Target Growth: 6.5%

Actual Growth: 5.35%

"S and T Policy and Approach during the Ninth Plan

-Need for mounting efforts to control population and improve the levels of food security, economic growth, literacy, health and so on, apart from realising the technological strengths in the emerging global industrial/ economic environment by optimal utilisation of the S and T Systems in India.

-Scientists with exceptional capabilities should be nurtured and supported fully by offering them, with in the country facilities comparable with international standards.

-To be in the forefront in some of the chosen fields, the research programmes should be taken up on a mission mode through appropriate re-structuring and re-orientation." (PCf, 1997)

DBT's goals remained the same as in the previous plan period. The only change was a new focus on the national directive to all S&T departments to "make a mark in the light of the international control regimes pertaining to IPR and TRIPS for protecting the interest of the country" (ibid) and a necessity for "India to emerge as global R and D platform" (ibid, 10.15). The new policy direction was based on a growing (and documented) distrust of partnership arrangements with developed countries that advantage those countries at India's expense. The focus was thus on technological self-reliance, control over IPR (and related organisations like WTO etc), building local innovation capacity and R&D collaborations with global research institutions.

'Genome mapping and sequencing' was selected as a 'thrust' area of DBT with a goal of "strengthening, expansion and operationalisation of a country-wide network in bioinformatics" (PCf, 1992: 10.1.35).

The "International Centre for Genetic Engineering and Biotechnology (ICGEB)⁶," was established in New Delhi as one of the 3 autonomous research institutes promised by the 8th five-year plan. In 1994, ICGEB became an autonomous centre under the United Nations Industrial Development Organization (UNIDO) with India and Italy becoming its largest

⁶ <http://www.icgeb.trieste.it/about-the-centre.html>

funders; ICGEB's current membership covers 64 countries, with an additional 21 pending ratification.

Telemedicine⁷ including telepathology (online sharing of patient pathology reports/images between members) network was launched in 1999 by Indian Space Research Organisation's (ISRO) INSAT (Indian Satellite) jointly with Department of Information Technology (DIT), Ministry of Communications and Information Technology (Mishra et.al, 2009) e.g. the National Rural Telemedicine Network etc. According to the ISRO 2012-13 report, 311 rural hospitals were networked with 80 superspeciality hospitals located in the major metros and 18 mobile vans (ibid). The Sanjay Gandhi Postgraduate Institute of Medical (SGPGIMS) Lucknow, a pioneer in telemedicine since the early 2000s, currently boasts global linkages and has launched a School of Telemedicine and Biomedical Informatics to develop informatics skills. Today, India's telemedicine network is connected via V-SAT to the 53 *Heads of State* network in the Pan-African e-Network covering 53 hospitals and 53 learning centers; the South Asian Association for Regional Cooperation (SAARC) countries Telemedicine networks; the Oregon Health and Science University, Portland, USA etc (see <http://www.sgpgi-telemedicine.org>). The success of telemedicine and its rapid take-up has encouraged private sector participation. Private firms from mobile companies (BPL Mobile in Maharashtra) to private hospital chains (Apollo Hospitals, Fortis Hospitals, Escorts Heart Institute and Research etc) have made considerable investments (Mishra et.al, 2009). So much so, that the DIT issued a "Recommended Guidelines & Standards for Practice of Telemedicine in India" and "The framework for Information Technology Infrastructure for Health (ITI-H)" in an effort to regulate and standardise telemedicine practices. In 2005, the Ministry of Health and Family Welfare created the National Task Force on Telemedicine (ibid). ISRO's proposed HEALTHSAT, a dedicated health satellite, has been in the works since 2004 with plans to expand existing networks nationally and globally.

On September 7, 2001, Prime Minister Vajpayee presented the 'Biotechnology - A Vision - Ten Year Perspective' (*Vision* hereafter)– guiding document for the DBT for the 2001-2010 period. The vision 'Attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – specially for the welfare of the poor' (DBT, 2001). In its list of focus areas earmarked for public support, *Vision* ranked basic research in Genomics and Bioinformatics as the first two biotech areas. The Genomics development plan was inwardly focused on mapping the diseases and disorders afflicting the Indian population as well as the animals/organisms/plants/crops important to India (ibid). The Bioinformatics development plan targeted two goals. One goal was inwardly focused on increasing basic research capacity in bioinformatics along the lines of the inward-looking genomics development plan i.e. using bioinformatics capacity to benefit the Indian populace. The other goal targeted developing India's national advantage in the global market,

⁷ Defined as "remote monitoring of physiological data e.g. temperature and blood pressure that can be used by health professionals for diagnosis or disease management. ...also covers the use of information and communication technology for remote consultation between health professionals or between a health professional and a patient e.g. providing health advice by telephone, videoconferencing to discuss a diagnosis or capturing and sending images for diagnosis" (Royal College of Nursing; see http://www.rcn.org.uk/development/practice/e-health/telehealth_and_telecare).

- i) by building world-class infrastructure “data warehouses, ... mirror sites to decipher the international data...” e.g. “GDB, Protein Data Bank (PDB), Plant Genome Data Banks, Databases of European Bioinformatics institute (EBI)” and supporting cutting-edge speciality informatics-of-the-future like neuroinformatics, and,
- ii) by developing a home-grown talent-pool of qualified bioinformaticians to fill (inter)national manpower shortages in the field with plans to train “at least 200 personnel per year to have a core group of 1000 trained experts in five years ... and 15000-20000 in ten years” (ibid).

The policy trend away from self-reliance and or developmental goals towards “international competitiveness” or ‘global leadership’ aspirations in select areas of biotechnology was evident, although muted. For instance, e.g. the plan proposed to “make the country a major power in matters relating to IPR in biotechnology.”

2002-07 (Tenth Five Year Plan 2002-07)

Target Growth: 8%

Actual Growth: 7.7% (8.9% in the last 4 years).

The policy focus was still on skilled manpower and skilled job creation. There was a strong focus on bio-informatics and health-informatics with the NICNET⁸ being refocused as a nationwide medical database and health information reporting network for the medical and research community with the aim of bringing medical colleges within its network. Emphasis was also laid on talent-development from pre-college levels and using attractive funding incentives, incubators, laboratory spaces, internationally renowned faculty to reverse brain drain.

At the same time, there was an emphasis, rather urgency, to build state-of-the-art world class research facilities to i) attract Diaspora renowned in the field and keep young talent within India, while ii) progressing rapidly from self-reliance and increasing national advantage to capturing global market share. Towards this end,

“...a national facility for virus diagnosis and quality control of plants raised by tissue culture; programme on genomics, ... fourteen genetic clinics ...for providing molecular diagnosis and counselling for the common genetic disorders prevalent in

⁸ The National Informatics Centre (NICNet) was established in the 70's, initially with UNDP funding, and later by GoI. It was to link government departments at different levels, transfer benefits to the rural and weaker sections of society, map indigenous plant genomes etc. In the 90's NICNet was proposed for Management Information Systems (MIS) but it “failed to take off” by GoI's own admission in the 10th plan (PCg, 2002: 2.2.27). NICNet is now a satellite-based electronic network with 3 state-of-the-art National Data Centres (NDCs) in NDelhi, Pune, Hyderabad and 31 small DCs in state capital connecting 1200+ nodes. An ICMR-NIC joint initiative provides bio-medical and health information to the research and medical community including updates on diseases and health risks relevant to India. It is the designated IMC - Indian MEDLAR Centre (Medical Literature Analysis and Retrieval System (MEDLARS) of the National Library of Medicine (NLM) is one of the world's largest medical bibliographical databases, consisting of millions of medical reference in each database through V-SAT) (Mohan, 2002: 372).

the country. ...powerful computational capability for handling large-scale human genome sequence data for functional genomics programme, robotic methodologies for genotyping and Polymerase Chain Reaction (PCR) based diagnostics for common genetic disorders, ...mirror sites for genomics, 38 post-graduate, post-doctoral and one-year diploma courses, 19 additional courses and 5 Centres of Excellence in bioinformatics” are launched (PCg, 2002; 10.43; 10.47; 10.48). The problem is that churning out bioinformatician is difficult in reality. The subject of Bioinformatics requires expertise in two disparate fields, bioscience and IT. This implies studying two different subjects simultaneously however since pay scales of bioinformaticians are less than that of an IT or biosciences professional, the financial or time investment for qualifying in bioinformatics is ill-justified (Biostars, 2014; Levine 2014: 1304; Dr Kristina Obom in Langer, 2008: 21). For instance, since the DBT started the yearly Bioinformatics National Certification (BINC) examination in 2005 (<http://bioinfo.ernet.in/>) only 140 students have qualified in the nine times it has been conducted between 2005-2013 (Guptal et.al, 2014).

Proposed plans focused on expanding the BTISNet (see 7th plan) to launch BioGrid India, “setting up of teraflop supercomputer facilities for bioinformatics; establishment of a National Bioinformatics Institute for carrying out various activities like policy making; establishment of a Centre for Genome Informatics for carrying out research related to genomics and proteomics that include database mining, computational gene discovery, sequence similarity searching, gene expression analysis” (ibid:10.114). Currently 100 databases are available on BTISNet including “mirror sites of internationally recognized genomic databases such as GDB, Protein Data Bank (PDB), Plant Genome Data Banks, Databases of European Bioinformatics institute (EBI) and public domain bioinformatics software packages are also available on the BIOGRID” for indigenous “unhindered mining of high quality data from well established primary and secondary information sources” (BTIS, nd).

In terms of policy direction, at the time of writing the 10th plan, bioinformatics had graduated from being an emerging field that could fulfil national developmental goals (see 7th, 8th and 9th plan) to a field that was “expected to be all pervasive and have far-reaching impact” where “it has become imperative for India to develop technologies, products and services of international cost and quality and become a global leader at least in some selected fields. Pursuing purposeful R&D is the only way to meet this challenge” (ibid: 10.159). Yet, there was a sense of wariness, a fear of losing the national ‘edge’ by trying to achieve too much too soon as the plan cautions against complacency and failure - “however, we have to be careful not to fritter away our scarce financial and human resources by trying to tackle all the areas” (ibid). The desire for global leadership is evident, but only “in selected fields” and bioinformatics, given the nation’s globally successful experience in IT and pharmaceuticals, was a natural choice and the proposed bioinformatics expansion plans involving substantial public spending commitments bear testament to that fact.

In-line with this policy direction, the 10th plan identified basic research in bioinformatics and nanotechnologies as sectors “which are expected to be all pervasive and have far-reaching impact” with earmarks for long-term R&D funding. According to the Working Group on IT for the 10th 5-yr plan, long-term funding was assessed for projects that were considered “uncertain and the gestation period could be more than 10 years. Such technologies may be

unattractive for private sector funding and therefore, long term R&D will have to be funded by the government” (ibid: 10.161). Thus, funding for bioinformatics including telemedicine R&D in the 10th plan was almost entirely publicly supported as they were yet to be considered attractive for funding by the private sector, VCs, or FDI sources. Interestingly, “large database” development was earmarked for short-term funding, i.e. projects with 1-3 year gestation periods, “immediate commercial potential and, therefore, should be funded to a large extent by industry with minimum support from the government funds” (ibid).

Furthermore, the 10th plan proposed “international cooperation” only for long and medium-term projects, but not for the short term ones and, appeared to be in a position to cherry pick the institution or country with whom to collaborate. For instance, the 10th plan noted that “India should seek international cooperation in these areas, based on the strength of cooperating countries, institutions, research labs or industries” (ibid) while the bioinformatics strategy noted that “Cooperation with India has been sought by several countries in this emerging field of Bioinformatics in view of the progress made and expertise developed” (BTIS, nd). At the time of writing the 10th plan, India’s Apex Bioinformatics centre was also the designated referral centre for UNDP/FAO/UNIDO’s regional agricultural information network/database (FARM programme); the DBT had already been networked with similar centres in China, Indonesia, Philippines, Thailand, Vietnam, Israel, Poland, Turkey and Malaysia.

Achievements of the 10th plan period (as laid out on 19/12/2007 at the presentation of the 11th plan),

- 1985-86: started MSc/MTech programs in 5 Universities, now 63 (22 programs added in 2002-07). Including MSc/MTech/PhD in Bioinformatics.
- 35 biotech facilities; 1 biotech park at Lucknow, Uttar Pradesh; 5 biotech incubation centres at (Hyderabad, Bangalore, Kochi, Chandigarh, Solan).
- Nationwide BTISNet covering 65 institutions with 1200+ bioinformatics peer-reviewed publications and 3500 biology/biotechnology research papers published.
- DBT launched *Small Business Innovation Research Initiative* (SBIRI) with funding managed by the *Biotech Consortia India Ltd.* (BCIL; a *Special Purpose Vehicle* (SPV) fund manager); by 19/12/2007 (i.e. at the time of presentation of the 11th plan) 10 such PPP proposals had been recommended for support.
- Successfully decoding genome of rice chromosome 11.
- India hosted The Fifth International Conference on Bioinformatics (InCoB 2006) jointly organised by Department of Biotechnology, Govt. of India New Delhi, Jawaharlal Nehru University, New Delhi and Indian Institute of Technology Delhi, under the aegis of Asia Pacific Bioinformatics Network (APBionet). 400 scientific presentations are made on seven different Bioinformatics topics.⁹
- Drugs and Pharmaceuticals Sector de-licensed in 23 September 2005 (FIPB, nd) in a move to decrease bureaucratic red tape to soften the adverse impact on the pharmaceutical reverse engineering industry following a change in TRIPS/patent-regime in Jan 2005. Patents for drugs were amended on 22 March 2005 to meet WTO demand for a product patent regime. However, India managed to negotiate the inclusion of a clause for ‘compulsory licensing’ controlling high-costs of ‘life-

⁹ <http://www.scfbio-iitd.res.in/seminar/incob.htm>

- saving drugs' (in 2013 Novartis lost under this clause). Before March 2005, India's patent law 1970 only required patents for 'process' and pharma/drug manufacturers could copy drugs and sell them in India and other countries with similar regulatory environments.
- National Board of Accreditation (NBA) of technical education joined the 'Washington Accord'¹⁰ as a provisional member to "ensure acceptance of its accreditation procedure amongst the member countries of the Accord" (IEA, nd). As of 13 June 2014 the NBA has become a full member, although, only those NBA accredited courses in NBA accredited Tier 1 institutions are recognised by other signatories (ibid).

2007-2012 (Eleventh Five Year Plan 2007-2012)

Target Growth: 9% (10% towards the end)

Actual Growth: 8%

The biotechnology research objectives were included under the chapter "Innovation and Technology" with four "major deliverables"- "Human Resource Development—Biotechnologists with expertise in Genomics, Proteomics and Metabolomics, Development of 'Info-bio' and 'Info-bio-nano' manpower" (PCh, 2007: Annexure 8.2 (pp190))

The guiding rationale for the DBT was still developmental (i.e. biotech to raise the quality of life for the poor, inclusive growth through employment opportunities etc). However, DBT's "**ultimate objective** is to make India globally competitive in the emerging bio-economy by converting the country's diverse biological resources to useful products and processes. Developing a strong biotechnology industry and technology diffusion capacity is critical for fulfilling this objective."

India's ambition of global leadership in biotech, which had begun to take shape in the 10th plan, became a stated end-point in the 11th plan (PCh, 2007: Chapter 8.54 (pp177)).

The 'National Biotechnology Development Strategy' in 2007(NBDS, 2007) was launched.

"Capabilities in S&T, therefore, are reckoned as a benchmark for establishing the status of the development of a nation. **India must occupy a frontline position in this listing.** The Eleventh Five Year Plan approach to S&T will be guided by this **ambition** and emphasis will be on" (PCh, 2007: Chapter 1.3.48 (pp30)):

- cross pollinating all S&T departments for basic research.
- hi-tech 'manpower' development and better S&T infrastructure.
- International linkages and membership/participant-status in global S&T projects.

The deficits identified are,

"relatively low investment in R&D by the corporate sector, and the lack of synergy among R&D institutions and universities. The present output of about 450 doctorates per annum in Engineering and Technology"(PCh, 2007: Chapter 1.3.48 (pp30)).

To achieve 'global leadership' goals the 11th plan's focus areas were (note: this is the 11th plan's focus areas, not just DBT's goals and thus they are shared by DBT, SCIR, CSIR, DIT etc),

"The priority areas for the Eleventh Five Year Plan Focus ...diagnostics, implants,

¹⁰ Estb 1989; international benchmark for engineering degrees; initial signatories UK, Ireland, USA, Canada, Australia, New Zealand (IEA, nd).

devices, medical bioinformatics, clinical research, stem cell research and regenerated medicine. Nanobiotechnology applications for drug, delivery, biosensors, microbial prospecting for novel compounds, genes, bioenergy and bio-fuels, bioremediation, and so on ...International cooperation activities matching national needs and the above priorities, will also be accelerated” (PCh, 2007: Chapter 8.55 (pp178)).

For the DIT, the goal was to strengthen R&D (by strengthening infrastructure and manpower skilled in IT) and focus areas included grid computing, high performance networking, bio-informatics and nanotechnology (PCh, 2007: Chapter 12.2.24 (pp437)). DIT went beyond bioinformatics to the next step “convergence of bio-info-nano technologies and cognitive science” (PCh, 2007: Chapter 12.2.25 (pp437)).

The challenges to achieving this global ambition as identified by the 11th plan were,

- “...creation of investment capital,
- technology transfer and technology absorption,
- patentability and intellectual property,
- affordability in pricing,
- regulatory issues and public confidence and
- tailor-made human resources related to all these aspects.” (ibid)

BOX 1

Likewise DBT **proposals to overcome these challenges** were,

- “...human resource development” incl. “smarter re-entry for our scientists abroad,
- new and varied models of creating an innovation-friendly environment,
- R&D in small and medium size companies,
- newer ways of collaborating with large companies,
- establishing centres of excellence and translational research centres,
- remodelling life science departments in universities/institutions,
- establishment of technology management centres,
- promoting dynamic biotech regional clusters,
- establishment of biotechnology parks and incubators,
- and setting up of biotechnology regulatory mechanisms” (PCh, 2007: Chapter 8.54 (pp177-178)).

The 11th plan’s proposals were focused on the ‘thrust’ areas identified earlier. “Interdisciplinary ‘grand challenge’ projects would be taken up in areas of national importance, where biotechnology interventions can bring about significant value addition, cost effectiveness and competitiveness in product and process development. These would be implemented through special management, administrative and organizational structures for time-bound results. Some of the areas identified for this purpose include: ...(v) diagnostics for health care; ...(vii) stem cell biology and regenerative medicine; and (viii) bioengineering for implants and medical devices” (PCh, 2007: Chapter 8.59 (pp178)).

For instance (below are the goals of BOX 1 in greater detail),

- Proposals to strengthen R&D focus (see BOX 1 above) on “Strengthening bioinformatics R&D and infrastructure in terms of higher supercomputing capabilities, expansion of biogrid, human resource development, linkages with industry, institutional mechanisms for software development and validation, development of an Indian portal site and

bioinformatics parks and clusters through PPPs, would also be taken up.” (PCh, 2007: Chapter 8.57 (pp178)).

“ ...Some of the other important R&D areas would be genomics, proteomics, pharmacogenomics, and in-silico drug design” (PCh, 2007: Chapter 8.58 (pp178)).

-Proposals to increase “R&D in small and medium size companies, newer ways of collaborating with large companies” (see BOX 1 above) sees the launch of 2 new schemes: Biotechnology Industry Partnership Programme (BIPP; PPP for those with ‘breakthrough’ potential) and Biotechnology Industry Research Assistance Council (BIRAC; R&D in SMEs), expansion of the 10th Plan’s SIBRI.

- Proposals “establishing centres of excellence and translational research centres, remodelling life science departments in universities/institutions” (see BOX 1 above) “...focus on translational and innovation activities, the existing autonomous institutions would be remodelled. This would require expansion of the scope of the institutions by building centres of translation, innovations and services along with focused networking. ...The Centre for DNA Fingerprinting and Diagnostics, Hyderabad, will undertake new activities such as a national facility for training in DNA profiling; ...creation of a national DNA database. The National Brain Research Centre, Manesar, will take up Neural Stem Cell research and set up a Clinical Research Centre for brain disorders and Brain Machine Interface. The Institute of Life Sciences, Bhubaneswar, will undertake translational activities for the development of DNA chip-based diagnostics and nano-medicine.” (PCh, 2007: Chapter 8.60 (pp178-179)).

New Institutions “include institutes for translational research in health science and technology; stem cell research and regenerative medicine; UNESCO regional centre for science, education and innovation; ...molecular medicine and medical genetics. ...three autonomous Translational Molecular Medicine Centres” (PCh, 2007: Chapter 8.61 (pp179)); Advanced Centre for Protein Informatics, Science, Engineering and Technology; 50 centres training and research institutes in Biotechnology, Bio-informatics, Nano-materials and Nanotechnologies etc. (PCh, 2007: Chapter 1.3.47 (pp30)).

“The national mission on nano science and technology would be a major new programme, designed to enable India to become a significant player in the global race by tapping the potential applications of nano science and technology ... would focus on basic research, infrastructure development for quality nano science and technology research, human resource development, forging international collaborations and most importantly, promoting PPP in the area of nano science and technology” (PCh, 2007: Chapter 8.69 (pp182)).

-Proposals for “promoting dynamic biotech regional clusters, establishment of biotechnology parks and incubators” (see BOX 1). One is a proposed knowledge park, “Mohali Knowledge City—Advantages of Clustering ...to build a knowledge city in Mohali, Punjab with a vision to promote innovation and startup companies. The cluster includes, on a single campus, the Indian Institute of Science Education and Research (IISER), National Agri-food Biotechnology Institute, Nanotechnology Institute, Management School, Technology and IP Management Centre, Business Centre, an Informatics Centre, Centralized Platform, Technology facility, a Good Manufacturing Practices (GMP) compliant Bio process Facility for Food and Nutraceuticals, a Technology Park for start-ups, and a host of other shared facilities.” (PCh, 2007: Box 1.3.3 (pp30)).

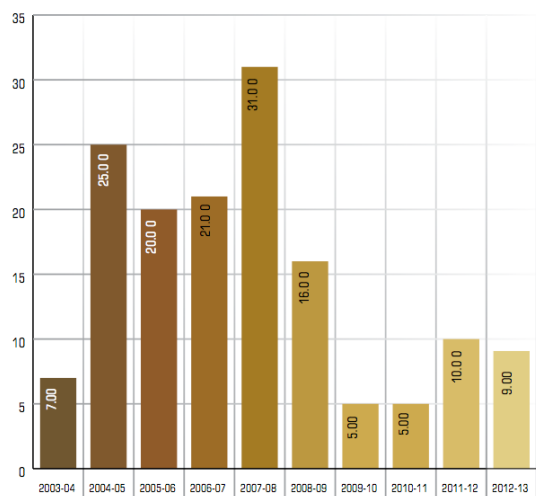
-Proposals “setting up of biotechnology regulatory mechanisms” (see BOX 1) aims to setup

a single window clearance for all biotechnology products- the proposed 'National Biotechnology Regulatory Authority' (PCh, 2007: pp178-180))

'Actual' achievements of the 11th plan,

- As of 2013 the BTISNet (launched in 1987) has 168 nodes/centers.
- 5 Centre of Excellences¹¹ (CoEs; Bose Instt., IISc., JNU, MKU, Uni. Of Pune, SCF-IIT). For instance, bioinformatics CoEs currently have eminent scientists from the diaspora, in-house trained manpower, state of the art infrastructure with their work focused on solving issues relevant to India e.g. IISc, Bangalore is working on “development of database from system level modelling and genome profiling of MTB; structural bioinformatics analysis and methodologies for genotype- phenotype mapping” for tuberculosis. TRC, Chennai is also using “annotation of genomes of mycobacteriophages, and developing bioinformatics tools for analysis of database” in tuberculosis as are JNU, IOB Bangalore etc. (BTISNet, 2013).
- 101 Bioinformatics Infrastructure Facilities (BIF)¹²,
- 5 MSc/M.Tech/Diploma in Bioinformatics
- 97 R&D Projects with 10 in Agriculture Biotech, 17 Medical Biotech, 33 Drug designing, 11 Tools for protein and Structural Biology, 9 Tools for genome sequence analysis and 10 more planned (BTISNet, 2013).
- North Eastern Bioinformatics Network (NEBInet) connects 29 institutions and is aimed at strengthening R&D in the far off northeast (ibid).

Bioinformatics growth rate 2003-13



Source: ABLE-Biospectrum, 2013: 28.

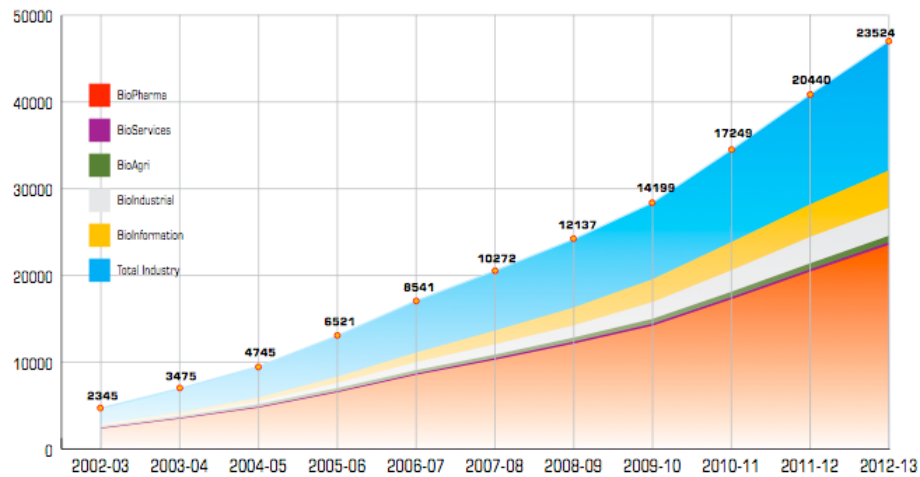
¹¹ Databases developed by CoE and others (BTISNet, 2013),

“• For protein structure analysis – Bose Inst. (ProFace, InteGeom, ConfPlot, ContPlot)
 • For structural bioinformatics – IISc, Bangalore (CSSP, MIPS, FAIR, SSMBS)
 • Genome comparison tools for TB strain identification – JNU, New Delhi
 • Database for viruses – Pune, Univ. (Viral protein Str., Viral genome resource, Antigen antibody interaction)
 • Buffalo Genome Information Resource (NDRI, Karnal & IASRI, New Delhi)
 • Genomic resource and knowledge base of plant parasitic nematodes of wheat & rice (IARI, New Delhi)
 • Discovery, annotation, validation & characterization of SNPs in Wheat using NGS data (BTIS, Ranchi & CCSU, Meerut).”

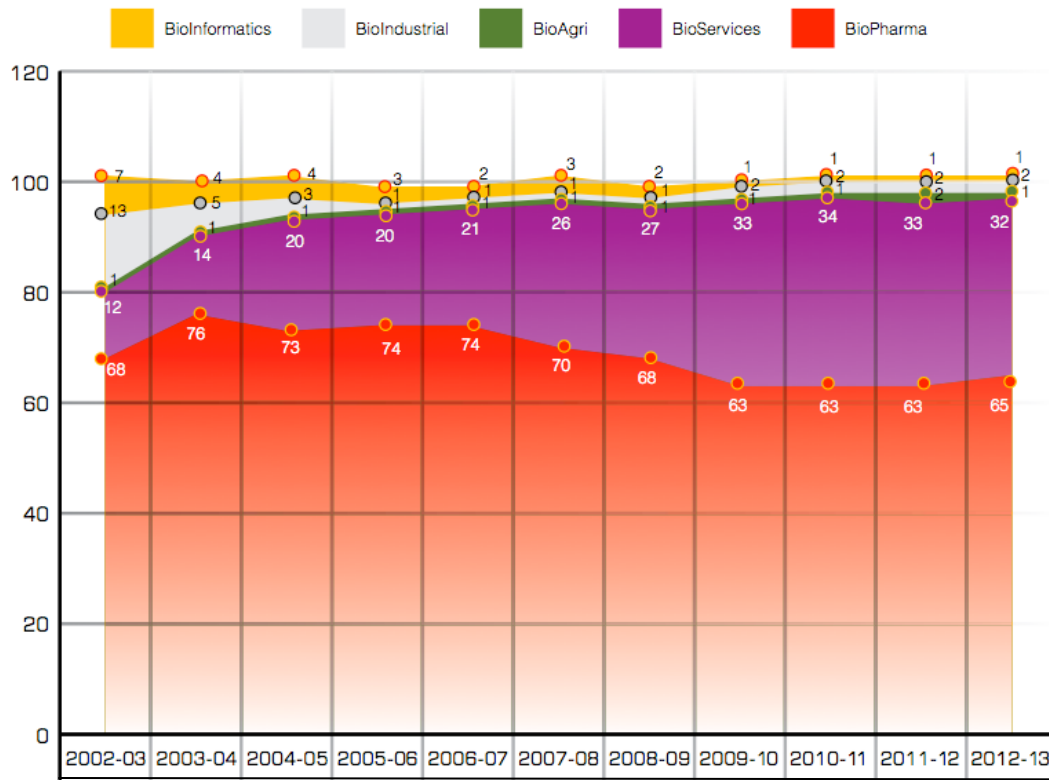
¹² In 2006-07 DBT launched the BIF for Biology Teaching through Bioinformatics (BTBI) “The goal of this scheme is to expose teachers and students to real-world of science and the use of bioinformatics (Cyber bioscience) in solving hard core biological problems.

Biotech industry in 2012-13

BioPharma	₹14,923 crore	17.69%
BioServices	₹4,329 crore	15.47%
BioAgri	₹3,210 crore	5.23%
BioIndustrial	₹772 crore	10.91%
BioInformatics	₹290 crore	9.14%
Total Industry	₹23,524 crore	15.08%



Source: ABLE-Biospectrum, 2013: 22.



Source: ibid: 29.

Table 2: Sector wise Project sanctioned in SBIRI scheme

Health care and related area	67
Agriculture	32
Industrial Product process	21
Instrumentation devices	9
Bioinformatics	2

Source: www.birac.org

A large number of institutions offering training/courses in Bioinformatics mushroomed during the IT boom years 1997-2002ish but shut down due to credibility and legitimacy deficits. Today, according to BioSpectrum only a handful of the GoI funded institutions are trusted by employers.

Achievements of the 11th plan (according to Report of the Working Group on Biotech (RWGoB, 2011): 12% of the budget was spend in “International collaboration/bioinformatics and HRD” (RWGoB, 2011: 2); 137 projects were funded in Bioinformatics among which 57 projects generated 50 publications with impact factor >7 (ibid: 19); 25 databases were launched (ibid: 19); 25 open domain use software were created (ibid: 19); 200 software packages (ibid: 29); 73 R&D projects (ibid: 29); 26 copyrights (ibid: 29); researcher exchange program with CNRS, France (ibid: 73); 13 projects funded under INDIGO project of the European Research Area Network (ERA-NET) in India (ibid: 73); DBT-AIST Japan project among which one is bioinformatics (ibid: 74); Bioresources Database Development Programme - A digitized database of agro-plant has been launched using bioinformatics tools e.g “Inventory of Microbial Resources of India (MTCC)” (ibid: 90); Indo-Canadian “collaborative programmes in genomics, bioinformatics and food processing, involving the exchange of faculty and scholars (ibid: 101);

Seven new research institutions were established, one is the National Institute of Biomedical Genomics (NIBMG) Kalyani.

The 11th plan’s proposal to launch a single-window regulatory mechanism, the Biotechnology Regulatory Authority of India (BRAI), for all biotech related approvals failed to materialize and is stated as one of the 12th plan objectives, awaiting reintroduction to the parliament as a bill, but with modifications (PCi, 2013: 251)

2012-2017 (Twelfth Five Year Plan 2012-2017)

Target Growth: 8% (starting with 6% in 2011-12 and ending with 9% in the last 2 years)

Actual Growth: %

The 12th Plan is muted (almost) silent on the subject of bioinformatics. The word ‘bioinformatics’ is only mentioned twice, both times referring to the proposed new research institution ‘Bioinformatics and Computational Biology.’ The word ‘informatics’ is mentioned 4 times including the two references above, and twice as insignificant benefits of other projects. In the aftermath of the 2008 recession, the 12th plan appears to have moved away from the pursuing 11th plan’s ambitious goals in biotechnology and bioinformatics, at least on paper. Biotechnology no longer appears to be in the running as a vehicle for job creation or raising the standard of living. For instance, the 12th plan proposes e-governance, e-security, e-learning etc but is not e-health. There are proposals to expand or launch

computerised databases of patient records etc at various levels, tele-medicine nodes, but little or no involvement with classical bioinformatics. Even the report on the 11th plan's achievements never mentions the word informatics or bioinformatics (PCi, 2013: BOX 8.4: (pp 250)). The absence of bioinformatics is evident in the 3 statements below,

“For instance, biotechnology, which focuses on industrial enzymes, alternate energy, seed manufacturing, diagnostics, vaccines, discovery research and clinical services and biotech drugs, is emerging as an important focus area for the country” (PCi, 2013: Chapter 13.201 (pp 97)).

“13.148. Access to finance needs to be enlarged through alternative sources of capital such as private equity, venture capital and angel funds. This is crucial for facilitating the growth of knowledge-based enterprises which have high potential in the Indian context. Further, prospective enterprises in emerging areas such as nanotechnology, biotechnology, aerospace and defence applications would also require such alternative sources of finance since traditional channels are unable to meet their needs” (PCi, 2013: Chapter 13.148 (pp 86)).

“62. Moving to a higher growth trajectory will require focussed institutional support and incentivise the clusters to foster innovation, encouragement to maximise investments in enhancing manufacturing capacities and aggressive drive for creation of ‘Brand India’ image in select segments including biopharmaceuticals/biosimilars and Indian systems of medicines” (PCi, 2013: 120).

In stark contrast, the 2011 *Report of the Working Group on Biotechnology* (RWGoB, 2011; discussed later) under the DBT, contained a detailed report of gaps, challenges and recommendations for developing/expanding the bioinformatics sector – it was intended as a guiding report for the 12th plan's biotech strategy. Similarly, both the National Biotechnology Development Strategy (NBDS; discussed later) in 2007 and 2014 contained detailed analyses of the bioinformatics sector with considerable page count devoted to the subject. Nevertheless, very little of that made it to the 12th plan document. It may very well be that a detailed discussion of the development of the bioinformatics sector was intended for the NBDS 2014 document and there was little need to address it in the plan document. This could also imply a conscious effort to distance/separate bioinformatics sector from the ‘inclusive growth’ goals of the 12th plan and allow it to pursue its ‘global leadership’ goals. Either way, the recommendations of the RWGoB (2011) were intentionally left out or the answer as to why that is requires further research.

DST (12th plan Budget allocation Rs 21,596 crores)

On the other hand, the DST goals for basic research are heartening for bioinformatics, albeit indirectly through the proposed support of basic research(ers). DST's stated goal of increasing India's basic research capacity is evident in its section heading “Scenario in Basic Research—Strategies for Global Positioning of India” and later “Strategic Interventions for India Emerging as One of the Top Six Global Powers in S&T Sector” (PCi, 2013: 246-247). This is in line with the 11th plan's goals of India's leadership in S&T. To catapult India from 9th to 6th position globally in basic research, DST targets policies,

- increasing the then 14% YOY growth of peer-reviewed publications to 62,500 per year.
- increasing “R&D personnel” to 250,000.

One of the policies proposes increasing super-computing infrastructure but does not mention informatics or bioinformatics.

DSIR (incl. CSIR) (12th plan Budget allocation Rs 17,896 crores)

The Department of Scientific & Industrial Research (DSIR including CSIR) “promote industrial research, technology development and transfer to enable India to emerge as a global industrial research and innovation hub” (PCi, 2013: 261). Much like the DBT and DST, the phrase *bioinformatics* is conspicuously absent. Similar to the DBT and DST, proposals for new funding mechanisms, rejuvenation of existing institutions, PPP initiatives, international collaborative efforts, skilled human resource development initiatives, expansion of schemes supporting different stages and types of innovation, expansion of S&T research infrastructure including innovation clusters etc is expected to impact the bioinformatics sector along with others. Only under the heading “R&D in Clusters through National Laboratories”, the plan comes closest to targeting bioinformatics,

“Programmes of the National Laboratories in the Twelfth Five Year Plan would be undertaken across five clusters which are as follows: Biological Science, Chemical Science, Engineering Science, Information Science and Physical Science. There is a specific focus on Human Resource Development in cluster mode. The projects have been formulated to encompass intra-cluster, inter-cluster and trans-cluster entities covering the domains of mega projects, large mission projects, supra-institutional network projects...” (PCi, 2013: 261).

National Targets for S&T Sector for the Twelfth Plan

National Targets for S&T Sector for the Twelfth Plan

Global Share of Publications	:	>5 per cent
Global Ranking in SCI publications	:	better than sixth
Global Ranking in Number Patent Cooperation Treaties (PCTs)	:	better than tenth
FTEs in R&D Personnel	:	2,50,000
PhDs Outputs in Whole Science Sector	:	12,500 per year
Public–Private Sharing of Investments		50:50
Gender Parity in EMR Funding (PI Ratios)	:	better than 60:40
The Relative Global Rank in Patent Portfolio	:	better than ninth
Commercialisation of Patents	:	better than 5 per cent levels
Share of High Technology Content in Exports	:	better than 20 per cent
Global Ranking in Innovation Index	:	better than 25th
Establishment of Section 25 Companies	:	in select sectors

Source: (PCi, 2013: 274(Annexure 8.1)).

DBT (12th plan Budget allocation Rs 11,804 crores)

The DBT’s goals for the 12th plan period are once again framed within developmental objectives for “inclusive growth” and the phrase ‘bioinformatics’ is never used, at least on

paper. However, under the heading “Rejuvenate existing and establish new research resources, facilities and services” “genomic and proteomic facilities; new generation sequencing service units” are mentioned (PCi, 2013: 251-252). A host of “innovative funding schemes” are proposed with the objective of supporting PPPs that are likely to indirectly impact bioinformatics,

“Ignition Grant Scheme available to individuals or a team of individuals—in partnership with private investment agencies; schemes for creating and nurturing start-up for early-stage technologies; provision of ‘bridge funding’ firms to function between successive private equity funding or planning for IPOs; funding for technology access and acquisition and licensing and special investment incentives to industry for building more biotechnology/pharma special economic zones (SEZs). Biotechnology Industry Research Assistance Council (BIRAC) would be made fully operational in Twelfth Plan to assess and facilitate bio industry as per its mandate and manage funding through PPP schemes. The affordable health technology initiative with Wellcome Trust...” (PCi, 2013: 252).

Under “Promoting new-generation biotech industries” the plan is silent on bioinformatics although “nano-bio industries” finds a mention (ibid).

The only use of the phrase bioinformatics can be found under proposals for “New and autonomous research institutions” “...in emerging areas of translational research such as Bioinformatics and Computational Biology...” (PCi, 2013: Chapter 8.58.19(pp 253)).

The BTISNet run by the DBT proposes the following (i.e. the following are not contained within the 12th plan document but under the BTISNet’s own vision document),

- “Forth Coming Priority Areas (BTISNet, 2013),
- Establishment of Indian Institute of Bioinformatics (IIB)
- Establishment of Indian Data Centre in Biological Sciences
- Call for proposals for the development of software tools on analyzing NGS data
- Network project: Brainstorming on Identifying major network programs where the Bioinformatics could play to enhance and speed up of the R&D.
- Human Resource Development in Bioinformatics should be given emphasis.”

RWGoB 2011:

The Report of the Working Group on Biotech (RWGoB, 2011) recommended the following for DBT’s 12th plan objectives, but were ultimately left out of the 12th plan document (i.e. I could not find a mention),

- Centre for DNA informatics and Computational Biology under CDFD.
- A state of the art Crop Bioinformatics Centre

A Comparison table of NBDS 2007 and NBDS 2014:

National Biotechnology Development Strategy (NBDS), DBT, MST, GoI	
NBDS 2007	NBDS 2014
Title: The Future Bioeconomy: Translating Life Sciences knowledge into socially relevant, eco friendly and competitive products	None Note: Biotechnology regulation is stated as a “major challenge” in the first page. (page 3) Primary focus basic sciences, secondarily Translational/academia-industryspinoffs.(23)
30% of budget earmarked for PPP	
Biotech Industry Partnership Prog (BIPP)	

Expand Small Busi Innov Res Industry (SBIRI) – for SME's	
Biotech Industry Res Asst Council (BIRAC) – for academia-industry collab in R&D	
Refocus uni & HR dev towards courses in genomics, proteomics, bioinformatics etc.	<p>“Build top-notch competence in technologies directly relevant to the growing bioeconomy</p> <ul style="list-style-type: none"> -Existing technologies (e.g., genetic engineering, high throughput systems for DNA and RNA analysis, mass-spectrometry) -Emerging technologies (e.g., synthetic biology, systems biology, bioinformatics for data-intensive discovery, advanced proteomics, advanced imaging) -Effectively linked fundamental science with other sciences and technologies for novel bio-applications (e.g., nanoscience, material science, chemical biology, physical biology, ICT). <p>Instruments for implementation:</p> <ul style="list-style-type: none"> -New, multiuser, accessible Regional Advanced Technology Platforms with preferred university location, linked to incubators. -New centres on the lines of Centre for Cellular and Molecular Platforms (CCAMP), Bangalore for all bio clusters. -Advanced technology platforms linked to Inter-institutional Centres.” (page 5-6)
UNESCO Regional Centre for Science, Education and Innovation in Biotech estb in Faridabad, Haryana health services cluster; focus on bioinformatics + 6 other areas. (8)	The UNESCO center is estb. Proposal for “Establish 5 EMBL (European Molecular Biology Laboratories)-like centres in the country” (page 13).
“New Breed of Institutions to be Set Up in Critical Areas” incl Medical genetics and Genomics as 1 of the 8 proposed. (page 8)	NIBMG, Kalyani is up and running. Proposal to “incentivize establishment of Technology Development and Translational Cells in 50 research universities” (page 6)
Agrifood cluster in Mohali, Punjab to incl Nanotechnology centre	Estb Mohali cluster around 2010-2011; the nanotech institute is yet to be setup; the Bangalore cluster was already advanced.
50+ CoEs incl centers for Bioinformatics	15 CoEs setup. 35 centres failed to pass min criteria – got support for programmes. Proposal to setup Centres of Excellence and Innovation (CoEI's); DBT – partnered Centres of Excellence; Inter-institution centres; Virtual network centres. (page 15)
“Beefing up” infrastructure to incl. gene banks (page 8)	

	Under “new schemes to address gap areas” MSc program in Medical Bioinformatics is 1 of 5. (page 13).
	<p>Vision 2025: under Translational genomics: focus on pharmacogenomics; “More widespread genomic testing services”; “epidemiology and genomics”; “genomics education”; “Institutional Mechanisms for Human Genome Research” (page 27-28).</p> <p>Under “Genomics and Genetic Characterization: Livestock and Poultry ... using high density sequencing of genomic DNA/cDNA for SNP detection and development of SNP array. ...Application of genome-wide marker-assisted selection (GWMAS) for enhancement of production, FCR and disease resistance. Page 41. Similar DNA marker technology in creating databases in marine biotech etc. page 44.</p>
	See immediately below for gaps and challenges in bioinformatics sector**

** Under Human Resource development, the NBDS (2014: 59-60) identifies 8 different “gaps and challenges” in “(iii) Bioinformatics, Computational and Systems Biology” ranging from lack of people with expertise in bio & Informatics to lack of world-class teaching infrastructure etc. Then it continues to provide detailed recommendations to bridge the gaps such as attracting eminent Diaspora (INSPIRE) etc.

However, the document undertakes a full sectoral analyses of “Bioinformatics, Computational and Systems Biology” as a separate section (pages 69-73). The primary gaps and challenge of the sector are,

“1) Lack of National data policy and a National data centre. Very few software tools & databases are developed in India. Most of those that exist are not validated and are highly fragmented.

2) Lack of state-of-art computing facilities to analyze the voluminous data being generated and to carry out research at par with the world.” (NBDS, 2014: 69).

Recommendations are provided along two strands- developing infrastructure and developing manpower. For the former, solutions range from establishing high quality research centres, creating a National data centre & policy that complement and strengthen the existing BTISNet e.g. “India must have its own data centre where the nationally generated database can be deposited,” expanding/setting-up world class supercomputing facilities etc. There is recognition of the challenges of low-levels of translational activity in the sector, especially in commercialisation. Likewise, policies targeting PPP, incentivizing academia-industry partnerships, setting up more incubators to attract industry are recommended as solutions. Additionally, some novel promissory areas where significant gaps exist on a global level are identified for future policy focus as below,

“-Specialized tools for analyzing next generation sequencing data

- Systems Biology in medical and plant sciences

- Biotherapeutics development
- Computational tools for Synthetic Biology
- Personalized medicine utilizing bioinformatics, systems biology and next generation genomics.
- Development of data repositories for promoting translational bioinformatics
- Molecular e-resources based on 'omics' platforms e.g. consolidation of small RNA data being developed by many labs across the country.
- Health / Medical record e-resources
- Plant trait e-resources
- Clinical trial e-resources
- Bio-safety data e-resources
- Drug and drug target databases" (72-73).

"International Cooperation" is identified as a major vehicle for meeting DBT's goals including "Participation in Global Initiatives, ...to provide a platform ...for smooth global public-private partnerships, ...strengthen its national biotech service sector such that India is the first global choice as a biotechnology service provider be it in the area of genomics, proteomics, data-mining etc., ...Collaboration in higher education with the best in the, ...organise international scientific meetings twice a year to debate and discuss Scientific Grand challenges" with the "Ultimate Goal: By 2025 DBT international Cooperation should become robust enough such that foreign offices of DBT are required in USA, Europe etc., something like the BBSRC, DFID, Tekes offices." (ibid)

TABLE FOR 12TH PLAN OUTLAY

Source: RWGoB, 2011: 239.

		(Rs. in Crores)
Sl. No.	Name of Programme/Scheme/Projects	Twelfth Plan Outlay
	S & T Sector	
1.	Human Resource Development	600.00
2.	Promotion of Excellence and Innovation	600.00
3.	Research Resources Facilities and Services	700.00
4.	Bioinformatics, Computational and System Biology	200.00
5.	Basic and use Inspired Research	1500.00
6.	Translational Science and Strategic Research	2000.00
7.	Grand Challenge Programmes	800.00
8.	Bio-Clusters and Incubators	1500.00
9.	International Collaborations	300.00
10.	Biotechnology for Social Development	200.00
	Total (A)	8400.00
11.	Autonomous R & D Institutions	
	(a) Ongoing	
	(i) National Institute of Immunology, New Delhi	535.40
	(ii) National Centre for Cell Sciences, Pune	470.89
	(iii) Centre for DNA Fingerprinting and Diagnostics	450.00
	(iv) National Brain Research Centre, Manesar, Haryana	390.73
	(v) National Institute of Plant Genome Research, New Delhi	265.98
	(vi) Institute of Life Sciences, Bhubaneswar, Orissa	325.00

(vii)	Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram	235.00
(viii)	National Institute of Biomedical Genomics, Kalyani	295.00
(ix)	Regional Centre for Biotechnology, Faridabad, Haryana	589.46
(x)	National Institute of Animal Biotechnology, Hyderabad	344.00
(xi)	Translational Health Sciences and Technology Institute, Faridabad	594.00
(xii)	National Agri-Food Biotechnology Institute and Bio-processing Unit, Mohali, Punjab	792.35
(xiii)	Institute of Stem Cell Biology and Regenerated Medicine, Bangalore	600.00
(xiv)	Institute of Bio-resources and Sustainable Development, Imphal	150.00
(b)	New Institutions	
(i)	Institute of Bioinformatics & Computational Biology	400.00
(ii)	Institute of Marine & Microbial Biotechnology	400.00
(iii)	Biotechnology Regulatory Authority of India (BRAI)	200.00
(iv)	Institute of Biodesign, Bioscience & Bioengineering (includes Medical Centre)	450.00
(v)	Institute of Chronic Disease Science & Biotechnology	300.00
(vi)	Infectious Science & Biotechnology Institute in North East (linking to THSTI as partner for training & Education)	300.00
	Total (B)	8087.81
	I & M Sector – Innovation Support Schemes to Industry	
	Innovation Support Schemes to Industry (I&M Sector)	1400.00
	♥ Biotech Parks = Rs. 100 Cr.	
	♥ SBIRI = Rs.200 Cr.	
	♥ BIPP = Rs. 500 Cr.	
	♥ BIRAC = Rs. 250 Cr.	
	♥ New Initiatives = Rs. 300 Cr.	
	Total (C)	1400
*	Total (A+B+C)	17887.81

(* 10% of the total budgetary allocations would be made available for programs and schemes of North Eastern Region)

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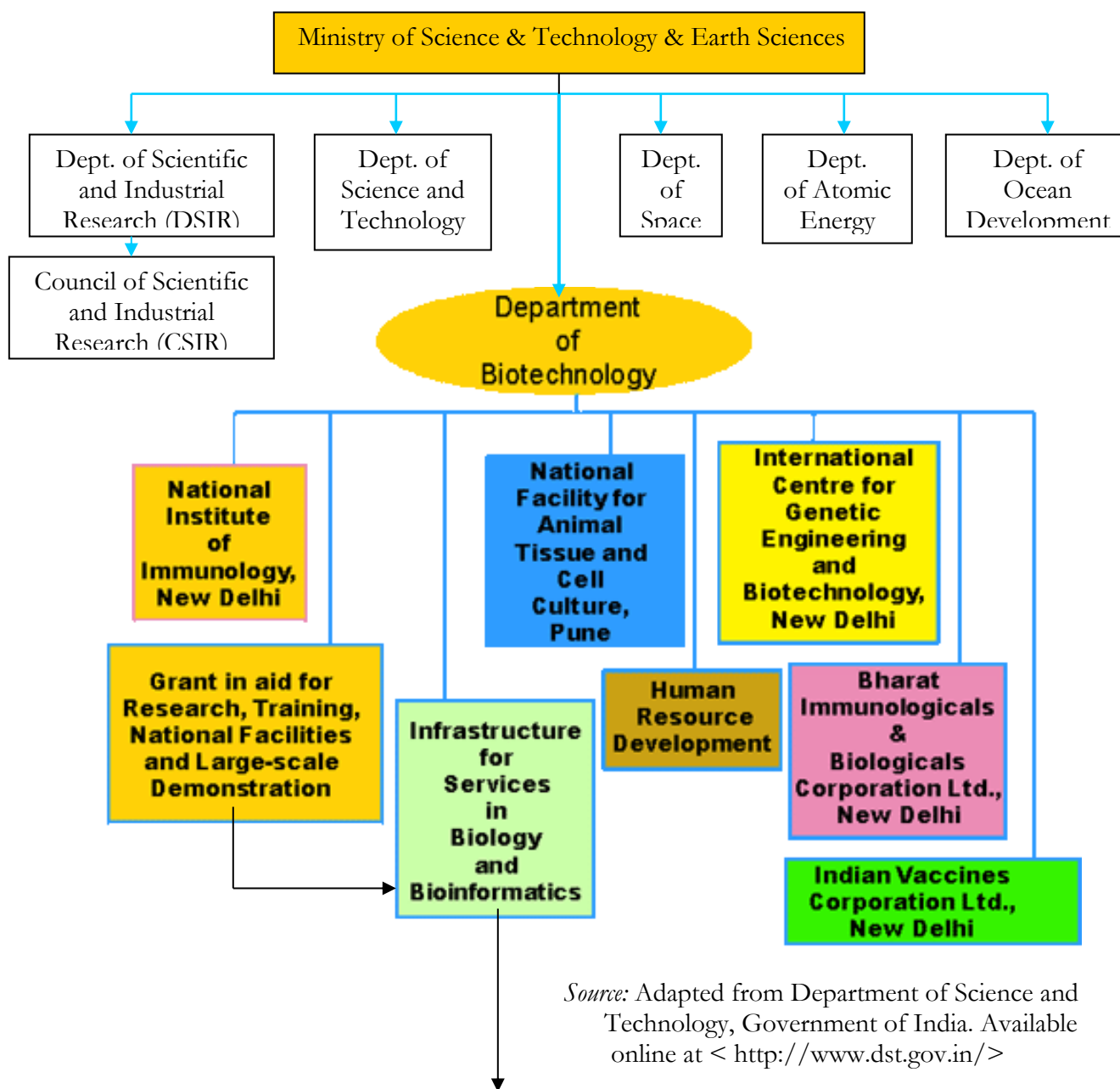
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ANNEXURE 1



Source: Adapted from Department of Science and Technology, Government of India. Available online at < <http://www.dst.gov.in/> >

Government of India – Department of Science & Technology Yearly Outlay on Bioinformatics 2005-2014				
Year	Category of DST Budget Outlay	E/A ¹³	Millions of GBP	Reference
2005-2006	Bioinformatics	A	1.66716	GoI-MST (2007-06) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2007-2008. Demand No. 83.

¹³ E represents estimated budget outlay. A represents actual spending.

				Department of Bio-Technology. Document 776/S&T/2007-6. Page 37-45. Available online at < http://dbtindia.nic.in/docs/2007-08ddg.pdf >
2006-2007	Bioinformatics	E A	2.2 2.2973	GoI-MST (2007-06) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2007-2008. Demand No. 83. Department of Bio-Technology. Document 776/S&T/2007-6. Page 37-45. Available online at < http://dbtindia.nic.in/docs/2007-08ddg.pdf >
2007-2008	Bioinformatics	E A	2.25 2.055	GoI-MST (2007-06) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2007-2008. Demand No. 83. Department of Bio-Technology. Document 776/S&T/2007-6. Page 37-45. Available online at < http://dbtindia.nic.in/docs/2007-08ddg.pdf >
2008-2009	Bioinformatics	E A	2 2.17488	GoI-MST (2007-08) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2008-2009. Demand No. 85. Department of Bio-Technology. Document 860 S&T/08-5. Page 29-37. Available online at < http://dbtindia.nic.in/docs/2008-09ddg.pdf >
2009-2010	Bioinformatics	E A	2 1.2	GoI-MST (2008-09) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2009-2010. Demand No. 85. Department of Bio-Technology. Document 2384 S&T/09-5. Page 28-40. Available online at < http://dbtindia.nic.in/docs/2009-10ddg.pdf >
2010-2011	Bioinformatics	E A	1.9 2.2	GoI-MST (2009-10) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2010-2011. Demand No. 86. Department of Bio-Technology. Document 656 Sc & Tech/2010-5. Page 27-39. Available online at < http://dbtindia.nic.in/docs/2010-11ddg.pdf > <i>The figures for the actuals are in the ref. below,</i> GoI-MST (2010-11) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2011-2012. Demand No. 87. Department of Bio-Technology. Document 729 S&T/11-5A. Page 31-45. Available online at < http://dbtindia.nic.in/docs/2011-12ddg.pdf >
2011-	Bioinformatics	E	1.9	GoI-MST (2011-12) Government of India Detailed

2012	(incl. new 'Grant for creation of capital assets' for Rs. 90m)	A	1.9	Demand for Grants of Ministry of Science & Technology for 2012-2013. Demand No. 85. Department of Bio-Technology. Document 860 S&T/08-5. Page 43-61. Available online at < http://dbtindia.nic.in/docs/2012-13ddg.pdf >
2012-2013	Bioinformatics (incl. new 'Grant for creation of capital assets' for Rs. 60m)	E A	2.298 2.038	GoI-MST (2012-13) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2013-2014. Demand No. 85. Department of Bio-Technology. Document 860 S&T/08-5. Page 46-66. Available online at < http://dbtindia.nic.in/docs/2013-14ddg.pdf >
2013-2014	Bioinformatics (incl. new 'Grant for creation of capital assets' for Rs.57.7m)	E	2.5	GoI-MST (2012-13) Government of India Detailed Demand for Grants of Ministry of Science & Technology for 2013-2014. Demand No. 85. Department of Bio-Technology. Document 860 S&T/08-5. Page 46-66. Available online at < http://dbtindia.nic.in/docs/2013-14ddg.pdf >